Stress Effect on Cation Re-ordering during Olivine-Spinel Phase Transformation in Fayalite

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Abstract No. Chen8363
Beamline(s): **X17B1**

Introduction: Subduction processes are believed to bring olivine, one of the most abundant minerals in Earth's upper mantle, to great depths where its high pressure polymorphs, wadsleyite and ringwoodite (spinel structure), are stable. Mechanism of the olivine-spinel transition and its effects on rheology are therefore important for understanding dynamic earth phenomena. Most of the previous studies on the transition have been carried out by examining samples recovered from high pressure and temperature using transmission electron microscopy (TEM). Two different mechanisms are proposed for the olivine-spinel transition: (i) stacking fault and cation reordering[1]; (ii) diffusion-controlled nucleation and crystal growth[2]. The first mechanism was supported by the TEM observation of a special orientation relationship between olivine and spinel phase (e.g. $(100)_{Ol}$ is parallel to $(111)_{Sp}$) during the transformation[3,4], and the second was suggested based by the absence of such an observation[4,5]. For the first time we studied the phase transformation by time-resolved the structure refinements using monochromatic x-ray diffraction at high pressure and temperature in the past a few years.

Methods and Materials: The experiments were performed using the large anvil press SAM85 at the superconductor wiggler Beamline X17B1. Two different P-T paths were followed in our experiments in order to study the sample under different deviatoric stress environment. In Path A, We compressed the powdered fayalite sample into the spinel stability field, and then we drove the olivine-spinel transition by increasing the temperature at a constant rate (0.03 K/sec). In Path B, we first annealed the sample at 3 GPa (olivine stability field) to release deviatoric stress in the sample, then compressed the annealed sample into spinel stability field, and finally drove the olivine-spinel transition by heating the sample at the same rate as in Path A. Time-resolved x-ray diffraction patterns were recorded by a translating imaging plate (TIP)[6] during the phase transformation.

Results: The transition temperature in the annealed sample is about 100°C higher than that in the stressed sample (Figure 1). Significant stress drop was observed in the stressed sample during the phase transition. A delay of cation re-ordering was found in both stressed sample and annealed sample, which indicates that the stacking fault and cation reordering mechanism is operative in both cases, by structure refinements. A volumetric change corresponding to the cation ordering into their crystallographic sites was also observed. TEM study on the recovered samples indicates that the phase transition in annealed sample may be driven by the local stress introduced by on-site volume deduction of olivine to spinel transformation.

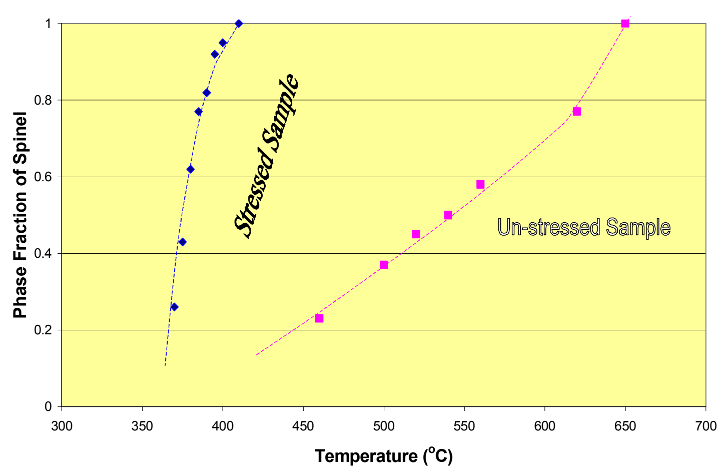

Figure 1. Phase fraction of transformed spinel as a function of sample temperature during the olivine-spinel transition in fayalite.

Acknowledgments: We would like to thank Z. Zhong at the NSLS for his technical assistance at the beamline.

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